A LABORATORY STUDY ON EFFECT OF TEST CONDITIONS ON SUBGRADE STRENGTH

A REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

In

Civil Engineering

By:

Rajesh Chauhan (10601024)

Department of Civil Engineering

National Institute of Technology

Rourkela-769008

2010

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Rajesh Chauhan (10601024)

Under the guidance of

Prof. M. Panda

Department of Civil Engineering

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CERTIFICATE

This is to certify that the thesis entitled, **"A LABORATORY STUDY ON EFFECT OF TEST CONDITIONS ON SUBGRADE STRENGTH"** submitted by Mr. Rajesh Chauhan in partial fulfilment for the requirements for the award of Bachelor of Technology Degree in Civil Engineering at National Institute of Technology, Rourkela (Deemed university) is an authentic Work carried out by them under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. M.Panda
Professor & Head,

Date: Dept. of Civil Engineering

National Institute of Technology
Rourkela-769008

ACKNOWLEDGEMENTS

I express my sincere gratitude to my guide Prof. M. Panda Head of Department of Civil Engineering for his constant inspiration and guidance without which it would have been difficult for me to complete the project. It is only for their constant suggestions that I have been able to finish my project work. I am also thankful to staff members of Highway Engineering Laboratory for their assistance and cooperation during course of experimentation.

Rajesh Chauhan (10601024)

8th Semester

B.Tech (Civil Egg.)

Contents **Page no.**

ABSTRACT

Design of the various pavement layers is very much dependent on the strength of the subgrade soil over which they are going to be laid. Subgrade strength is mostly expressed in terms of CBR (California Bearing Ratio). Weaker subgrade essentially requires thicker layers whereas stronger subgrade goes well with thinner pavement layers. The pavement and the subgrade mutually must sustain the traffic volume. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based upon the subgrade strength which is primarily dependant on CBR value for a laboratory or field sample soaked for four days. The subgrade is always subjected to change in its moisture content due to rainfall, capillary action, overflow or rise of water table. For an engineer, it's important to understand the change of subgrade strength due to variation of moisture content. This project is an attempt to understand the strength of subgrade in terms of CBR values subjected to different days of soaking and the corresponding variation in moisture content. It is observed that the CBR decreases and the moisture content increases for high degree of soaking

CHAPTER – 1

INTRODUCTION

1.1 Subgrade (Ref. - 1)

1.1.1 Definition

Subgrade can be defined as a compacted layer, generally of naturally occurring local soil, assumed to be 300 mm in thickness, just beneath the pavement crust, providing a suitable foundation for the pavement. The subgrade in embankment is compacted in two layers, usually to a higher standard than the lower part of the embankment The subgrade, whether in cutting or in embankment, should be well compacted to utilize its full strength and to economize on the overall pavement thickness. The current MORTH Specifications require that the subgrade should be compacted to 100% MDD achieved by the Modified Proctor Test (IS 2720-Part 7). For both major roads and rural roads the material used for subgrade construction should have a dry unit weight of not less than 16.5kN/m3.

1.1.2 Subgrade Soil

Soil is a gathering or deposit of earth material, derived naturally from the breakdown of rocks or decay of undergrowth that can be excavated readily with power equipment in the field or disintegrated by gentle reflex means in the laboratory. The supporting soil below pavement and its special under course is called sub grade. Without interruption soil beneath the pavement is called natural sub grade. Compacted sub grade is the soil compacted by inhibited movement of heavy compactors.

1.1.3 Desirable Property of Subgrade Soil

The advantageous properties of sub grade soil as a highway material are

- Stability
- Incompressibility

- Permanency of strength
- Minimum changes in volume and stability under adverse conditions of weather and ground water
- superior drainage, and
- Ease of compaction

1.2 Methods for determining Subgrade strength for designing new roads (Ref.-2, 3)

For the pavement design of new roads the subgrade strength needs to be evaluated in terms of **CBR** value which can be estimated by any of the following methods:

- Based on soil classification tests and the table given in IRC: SP: 72-2007 which gives typical presumptive design CBR values for soil samples compacted to proctor density at optimum moisture content and soaked under water for 4 days.

- Using a Nomograph based on wet sieve analysis data, for estimating 4-day soaked CBR values on samples compacted to proctor density.

- Using two sets of equations, based on classification test data, one for plastic soils and the other for non-plastic soils, for estimating soaked CBR values on samples compacted to proctor density.

- By conducting actual CBR tests in the laboratory.

The first, second and third method come in handy where adequate testing facilities are not available or the project is of such a size as to not to warrant elaborate testing procedures.

1.2.1 Quick estimation of CBR

PLASTIC SOIL

CBR= 75/ (1+0.728 WPI),

Where WPI= weighted plasticity index= $P_{0.075} \times$ PI
PI= Plasticity index of soil in %

$P_{0.075}$= % Passing 0.075 mm sieve in decimal

NON- PLASTIC SOIL

CBR= 28.091$(D_{60})^{0.3581}$

Where D_{60}= Diameter in mm of the grain size corresponding to 60% finer. Soil classification can be used for preliminary report preparation.

1.2.2 Typical presumptive design CBR values

Table- 1.1 Typical presumptive CBR values

DESCRIPTION OF SOIL SUBGRADE	IS SOIL CLASSIFICATION	TYPICAL SOAKED CBR VALUE IN (%)
Highly plastic clays	CH, MH	2-3
Silty clays and sandy clays	ML, MI CL, CI	4-5
Clayey sands and Silty sands	SC, SM	6-10

Table- 1.2 Typical presumptive CBR values

CBR VALUE	SUBGRADE STRENGTH
3% or less	Poor
3% - 5%	normal
5% - 15%	good

1.2.3 SELECTION OF MOISTURE CONTENT FOR SUBGRADE STRENGTH EVALUATION (Ref.-2,3)

Subgrade classification	Estimating Subgrade Moisture Content
Where the GWT is close enough to the ground surface to influence the subgrade moisture content.	• The subgrade moisture content for different soil types can be estimated by using the ratio subgrade moisture contents/ plastic limit which is about the same when GWT and climatic conditions are similar. • The most direct method is to measure the moisture content in subgrades at the time of the yr when the GWT is at the highest level.
Subgrades with deep GWT but where seasonal rainfall brings about significant changes in moisture conditions under the road.	• The possibility of local perched GWT and effects of seasonal flooding should, however, also be considered while deciding on GWT depth. Where such situations are encountered, the subgrade strength may be determined in terms of 4 day soaked CBR values. • Design moisture content can be taken as optimum content obtained from Proctor Compaction Test corresponding to maximum dry density.

1.3 Laboratory Procedure for CBR Test (Ref.-2, 3)

1.3.1 General

The CBR test was originally developed by O.J. Porter for the California Highway Department during the 1920s. It is a load-deformation test performed in the laboratory or the field, whose results are then used with an empirical design chart to determine the thickness of flexible pavement, base, and other layers for a given vehicle loading. Though the test originated in California, the California Department of Transportation and most other highway agencies have since abandoned the CBR method of pavement design. In the 1940s, the US Army Corps of Engineers (USACE) adopted the CBR method of design for flexible airfield pavements. The USACE and USAF design practice for surfaced and unsurfaced airfields is still based upon CBR today (US Army, 2001; US Army and USAF, 1994). The CBR determination may be performed either in the laboratory, typically with a recomputed sample, or in the field. Because of typical logistics and time constraints with the laboratory test, the field CBR is more typically used by the military for design of contingency roads and airfields. The thickness of different elements comprising a pavement is determined by CBR values. The CBR test is a small scale penetration test in which a cylindrical plunger of 3 in2 (5 cm in dia) cross-section is penetrated into a soil mass (i.e., sub-grade material) at the rate of 0.05 in. per minute (1.25 mm/minute). Observations are taken between the penetrations resistances (called the test load) versus the penetration of plunger. The penetration resistance of the plunger into a standard sample of crushed stone for the corresponding penetration is called standard load. The California bearing ratio, abbreviated as CBR is defined as the ratio of the test load to the standard load , expressed as percentage for a given penetration of the plunger.

CBR = (Test load/Standard load)×100

In most cases, CBR decreases as the penetration increases. The ratio at 2.5 mm penetration is used as the CBR. In some case, the ratio at 5 mm may be greater than that at 2.5 mm. If this occurs, the ratio at 5 mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions. The test procedure should be strictly adhered if high degree of reproducibility is desired. The CBR test may be conducted in re-moulded or undisturbed specimen in the laboratory. The test is simple and has been extensively investigated for field correlations of flexible pavement thickness requirement

1.3.2 Test Procedure

The CBR test is carried out on a compacted soil in a CBR mould 150 mm in diameter and 175 mm in height, provided with detachable collar of 50 mm and a detachable perforated base plate. A displacer disc, 50 mm deep to be kept in the mould during the specimen preparation, enables a specimen of 125 mm deep to be obtained. The moulding dry density and water content should be the same as would be maintained during field compaction. To simulate worst moisture condition of the field, the specimens are kept submerged in water for about 4 days before testing. Generally, CBR values of both soaked as well as unsoaked samples are determined. Both during soaking and penetration test, the specimen is covered with equal surcharge weights to simulate the effect of overlying pavement or the particular layer under construction. Each surcharge slotted weight, 147 mm in diameter with a central whole 53 mm in diameter and weighing 2.5 kg is considered approximately equivalent to 6.5 cm of construction. A minimum of two surcharge weights (i.e. 5kg surcharge load) is placed on the specimen. Load is applied on the penetration piston so that the penetration is approximately 1.25mm/min. The load readings are recorded at penetrations, 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6, 6.5, 7, 8, 9, 10, 11, 12, and 12.5mm.

The maximum load and penetration is recorded if it occurs for a penetration of less than 12.5 mm.

The curve is mainly convex upwards although the initial portion of the curve may be concave upwards due to surface irregularities. A correction is then applied by drawing a tangent to the curve at the point of greatest slope. The corrected origin will be the point where the tangent meets the abscissa.

The table gives the standard loads adopted for different penetrations for the standard material with a CBR value of 100%.

Table No – 1.3.1 Standard Load Used In California Bearing Ratio Test

Penetration of the plunger(inch)	Standard load (lb)	Penetration of plunger(mm)	Standard load (kg)
0.1	3000	2.5	1370
0.2	4500	5.0	2055
0.3	5700	7.5	2630
0.4	6900	10.0	3180
0.5	7800	12.5	3600

1.4 Scope of Work

The present scope of work for this project is to ascertain the CBR value under different soaking time conditions and to study the influence of moisture content developed in the samples under varying soaking.

1) To collect a particular soil sample and determine its basic physical property such as LL,PL,PI and grain size distribution
2) To study the soil under modified proctor compaction and determine the MDD and OMC for the soil sample
3) To carry out CBR Test for sample soaked in different times
4) To obtain moisture content for varying degree of soaking
5) To study the influence of soaking on subgrade strength

CHAPTER- 2

EXPERIMENTAL INVESTIGATIONS

2.1 General

The experimental work comprises in the following parts.

1. Determination of index property

- Liquid limit by liquid limit device
- Plastic limit
- Plastic Index
- Shrinkage limit

2. Particle size distribution

3. Estimation of maximum dry density and optimum moisture content by modified proctor test

4. Calculation of CBR strength

(i) Moulding the soil sample into standard moulds keeping its moisture content and dry density exactly same as its optimum moisture content and proctor density respectively.

(ii) Determination of CBR strength of the respective soil samples in moulds using the CBR instrument.

(iii) Soil sample is tested for its CBR strength after being soaked in water for 1 day, 2 days, 3 days and 4 days. Unsoaked CBR is also determined for each sample.

2.2 Brief steps involved

2.2.1 Particle size distribution

The Standard grain size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges.

2.2.2 Liquid Limit Test

This test is done to determine the liquid limit of soil as per IS: 2720 (Part 5) – 1985. The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid, but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande's liquid limit device.

2.2.3 Plastic Limit Test

Plastic limit is defined as minimum water content at which soil remains in plastic state. The plasticity index is defined as the numerical difference between its Liquid limit and Plastic limit

CHAPTER- 3

RESULTS & DISCUSSIONS

3.1 Index property

The result of index properties such as liquid limit, plastic limit, PI value are presented in Table - 3.1

Table – 3.1 Index properties of Soil Sample

Description of index property	Experimental value
Liquid limit	27.8 %
Plastic limit	17.89%
Plastic index	9.91%
Shrinkage limit	15.61%

3.2 Particle size distribution - The grain size distribution of this soil sample has been shown in Table – 3.2

Table – 3.2

I.S. sieve no.	wt. retained in (gm)	percentage wt. retained(gm)	percentage wt. passing
4.75 mm	17.66	1.766	98.23
2.36 mm	16.73	1.673	96.56
1.18 mm	14.02	1.402	95.16
425 µm	10.51	1.051	94.11
300 µm	2.65	0.265	93.85
150 µm	21.67	2.167	91.67
75 µm	40.62	4.062	87.61

Based on the above properties the IS Soil Classification for the soil sample under test is 'CL'

3.3 Modified Proctor Compaction Test

The result of modified proctor compaction test are represented in figure - 3.3.1

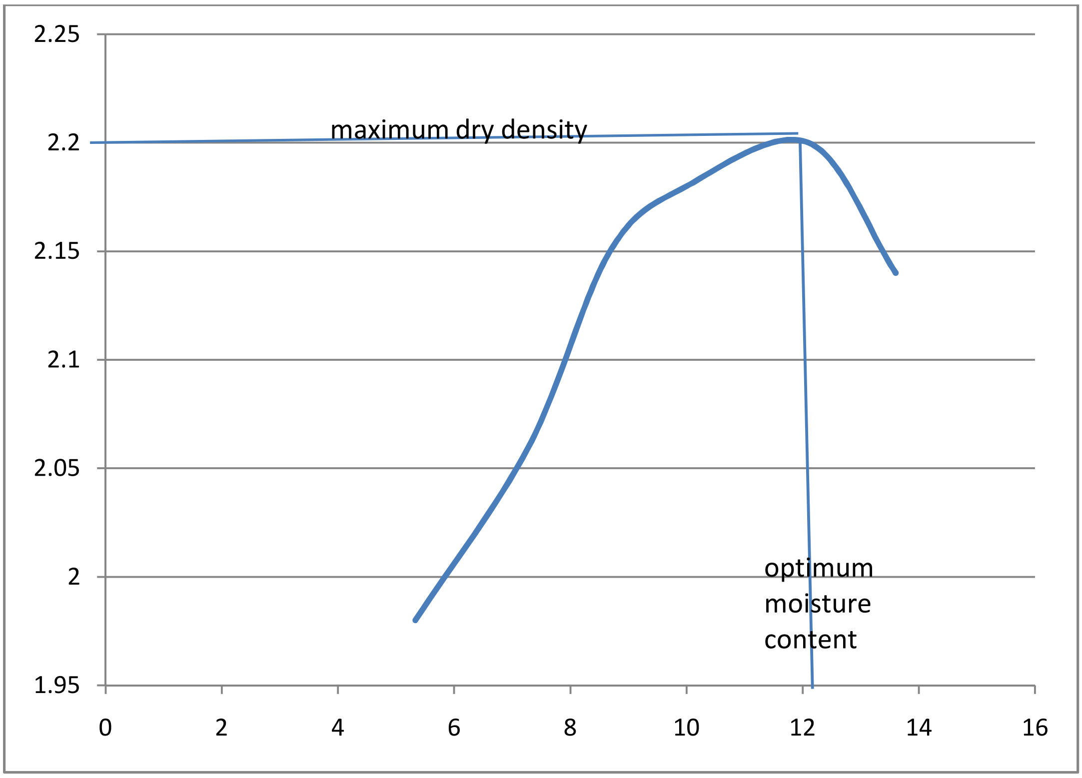


Figure – 3.3.1

From the above figure it is clear that,

MDD = 2.20 g/cc

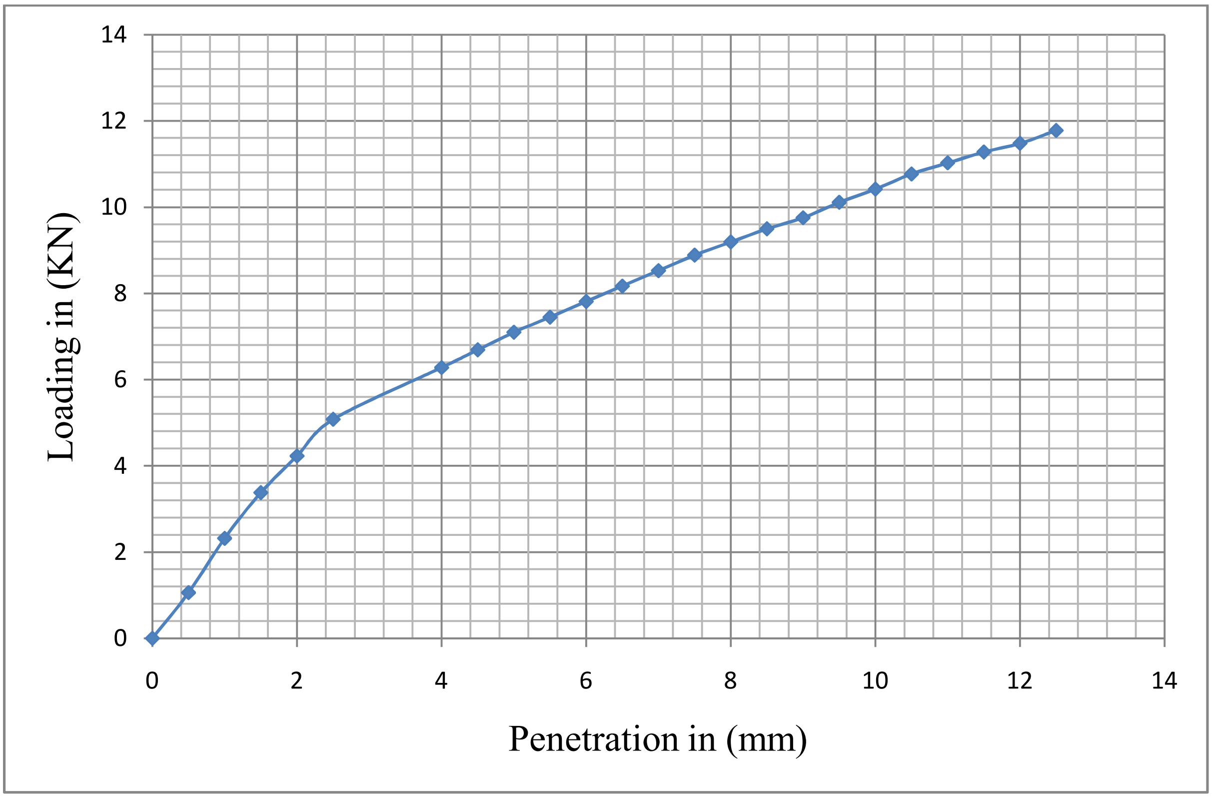
OMC = 12.1 %

3.4 CBR Test

The result of CBR test of soil sample under different times of soaking are presented in

1) Figure – 3.4.1, Un-Soaked (0 hrs)
2) Figure – 3.4.2, Soaked (12 hrs)
3) Figure – 3.4.3, Soaked (24 hrs)
4) Figure – 3.4.4, Soaked (36 hrs)
5) Figure – 3.4.5, Soaked (48 hrs)
6) Figure – 3.4.6, Soaked (60 hrs)
7) Figure – 3.4.7, Soaked (72 hrs)
8) Figure – 3.4.8, Soaked (84 hrs)
9) Figure – 3.4.9, Soaked (96 hrs)

1) Figure – 3.4.1, Un-Soaked (0 hrs)



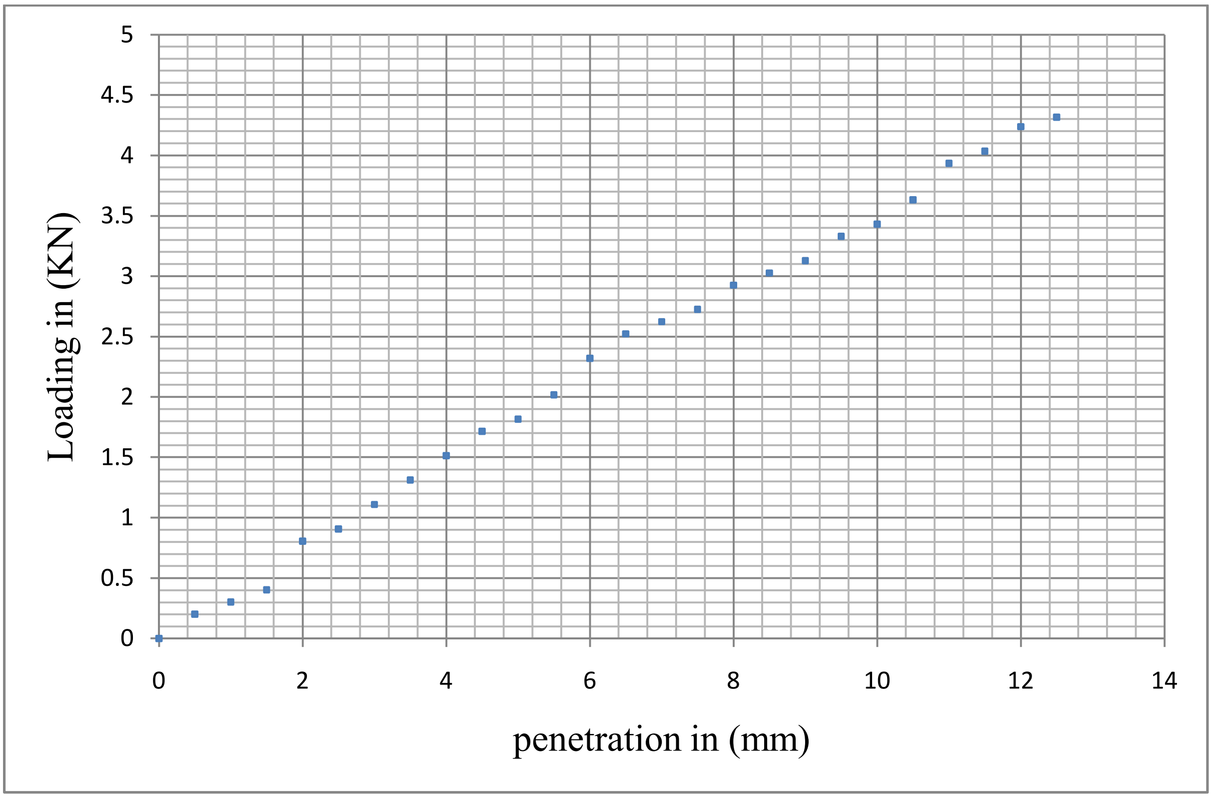
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (5.082)/ (13.440)*100

= 37.813%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (7.099)/ (20.160)*100

= 35.214%

2) Figure – 3.4.2, Soaked (12 hrs)



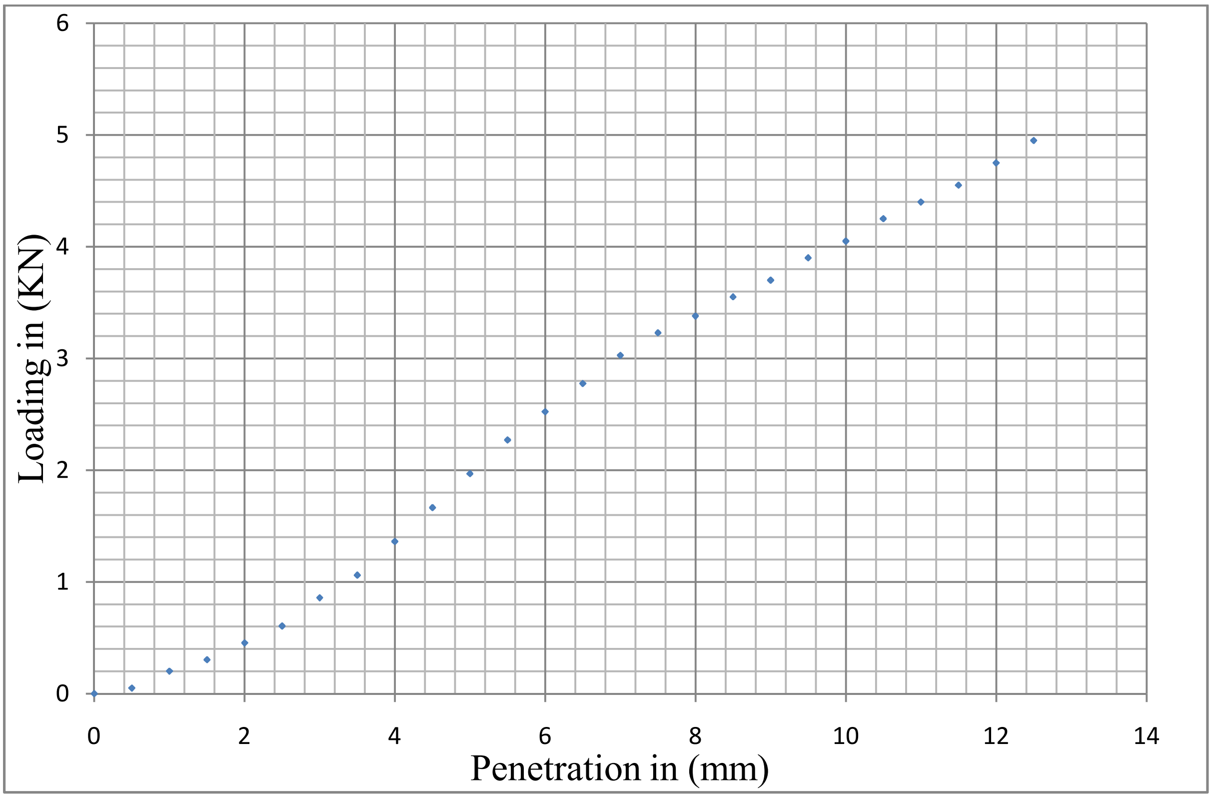
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (1.494)/ (13.440)*100

= 11.12%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (2.504)/ (20.160)*100

= 12.42%

3) Figure – 3.4.3, Soaked (24 hrs)



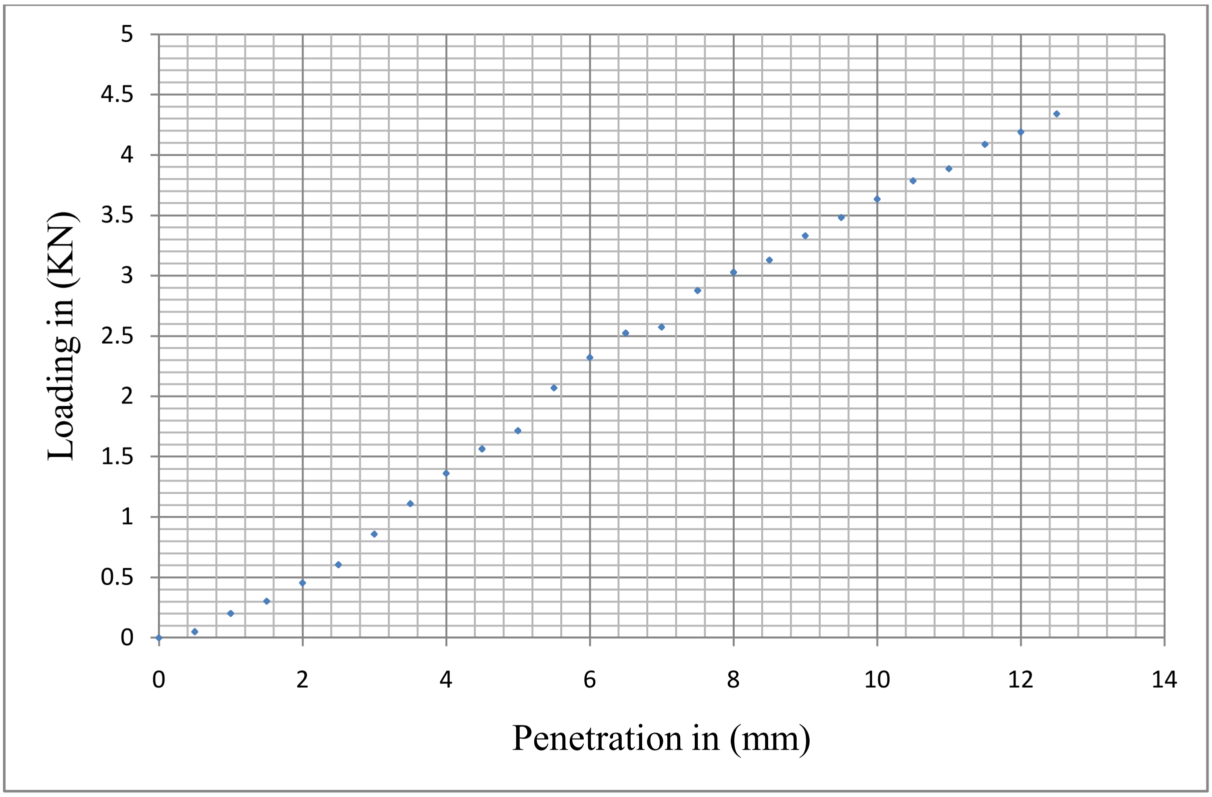
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (1.246)/ (13.440)*100

= 9.27%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (2.02)/ (20.160)*100

= 10.02%

4) Figure – 3.4.4, Soaked (36 hrs)



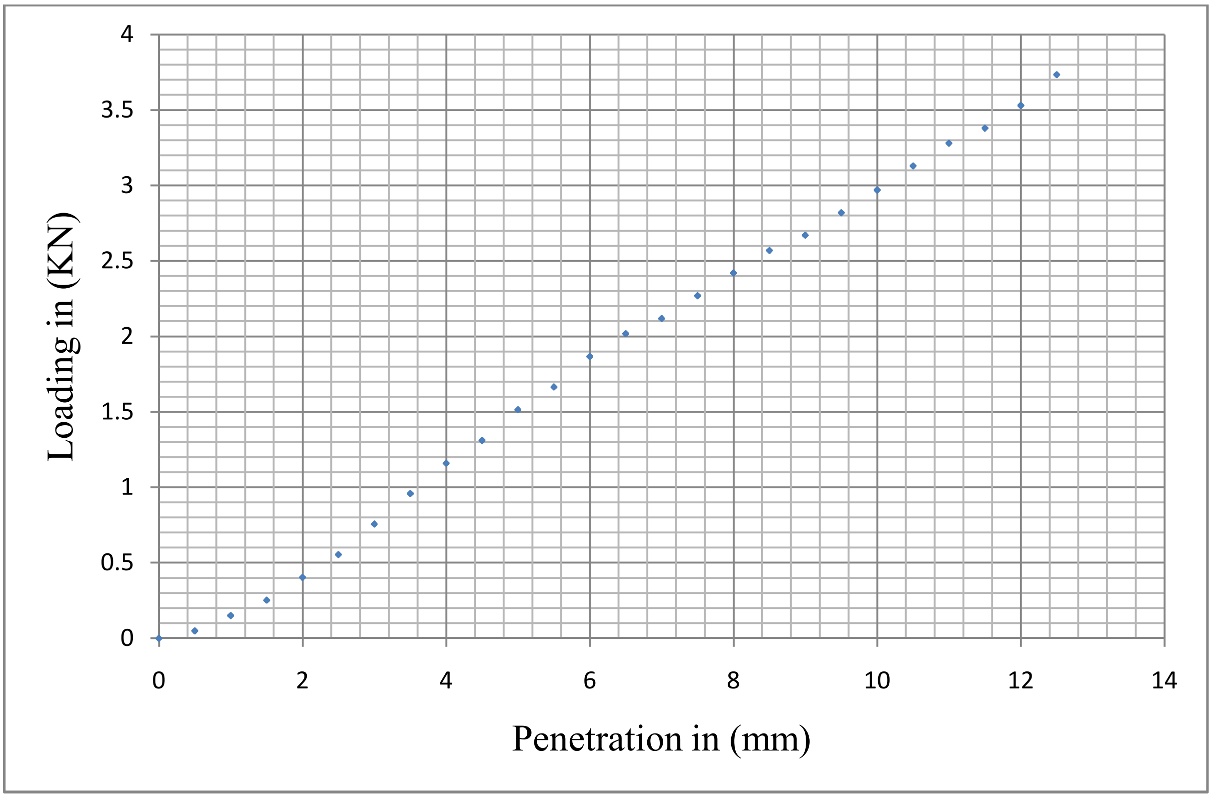
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (1.11)/ (13.440)*100

= 8.26%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (2.573)/ (20.160)*100

= 12.76%

5) Figure – 3.4.5, Soaked (48 hrs)



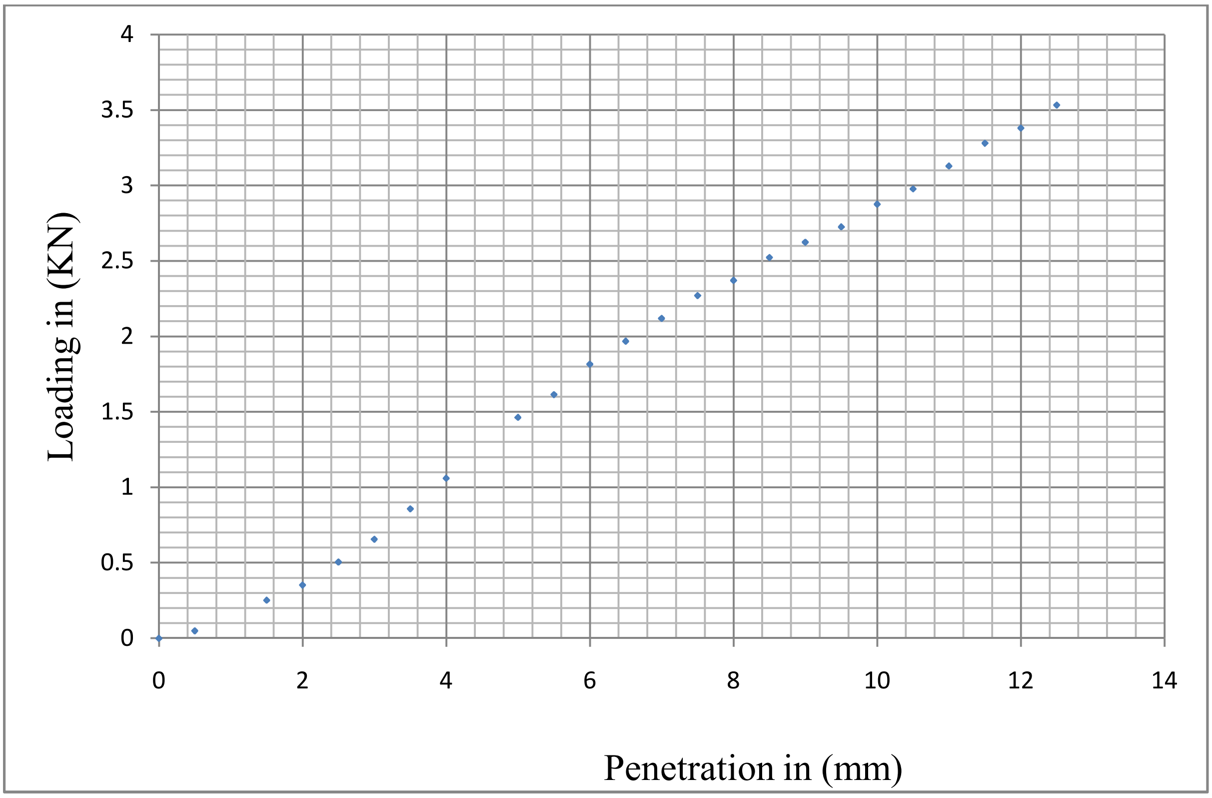
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (1.06)/ (13.440)*100

= 7.89%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (3.025)/ (20.160)*100

= 15.01%

6) Figure – 3.4.6, Soaked (60 hrs)



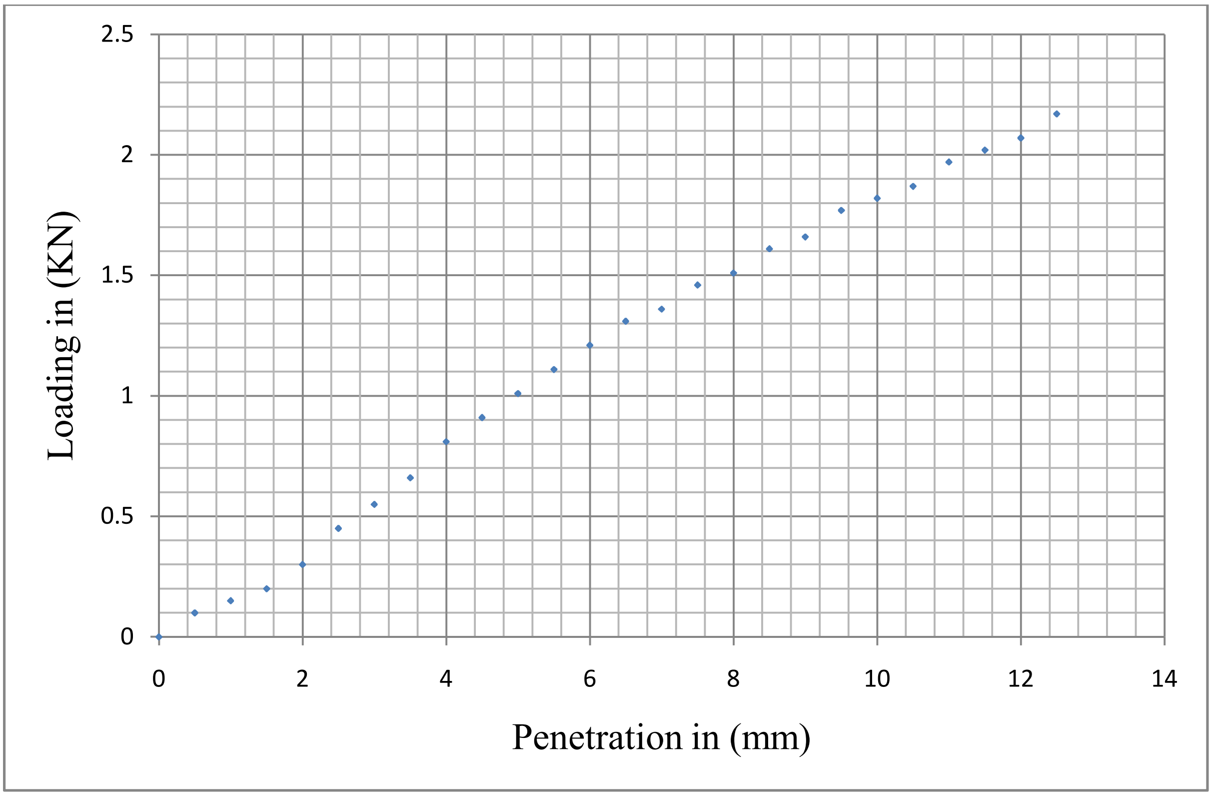
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (0.94)/ (13.440)*100

= 7.36%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (1.89)/ (20.160)*100

= 9.37%

7) Figure – 3.4.7, Soaked (72 hrs)



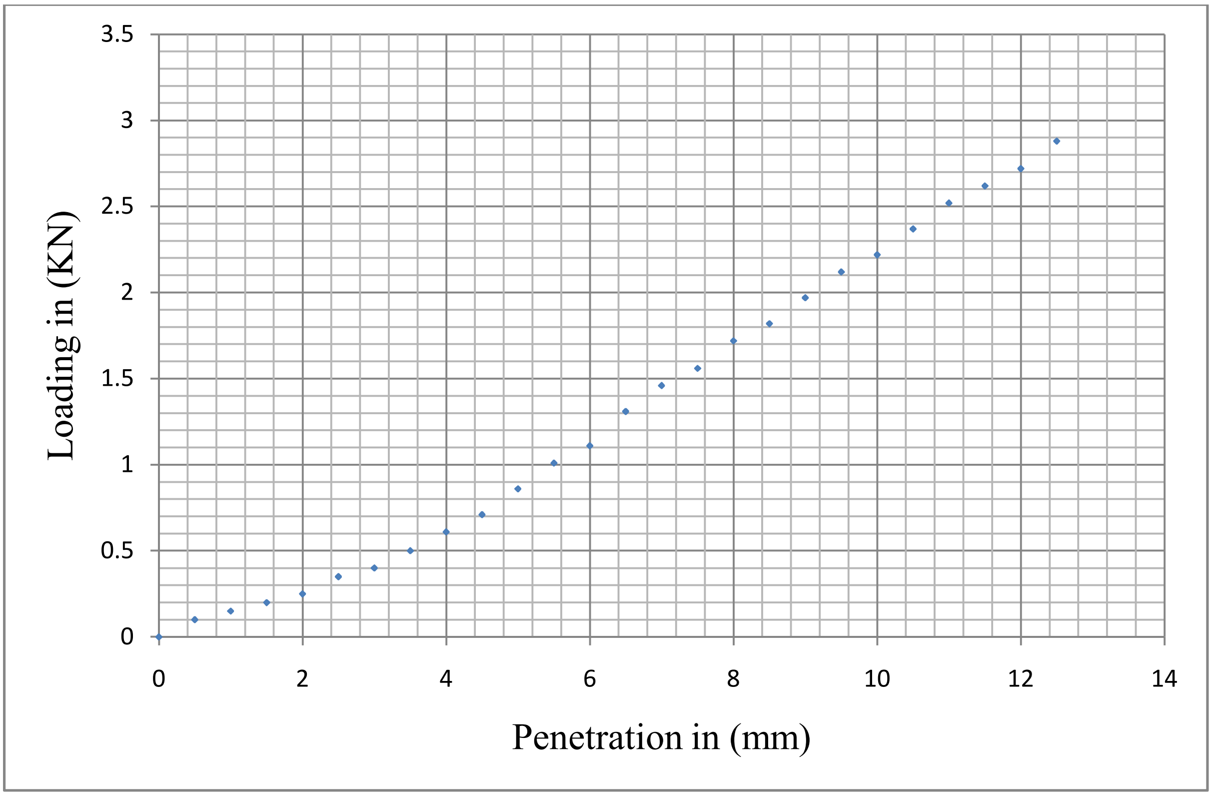
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (0.858)/ (13.440)*100

= 6.38%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (2.119)/ (20.160)*100

= 10.51%

8) Figure – 3.4.8, Soaked (84 hrs)



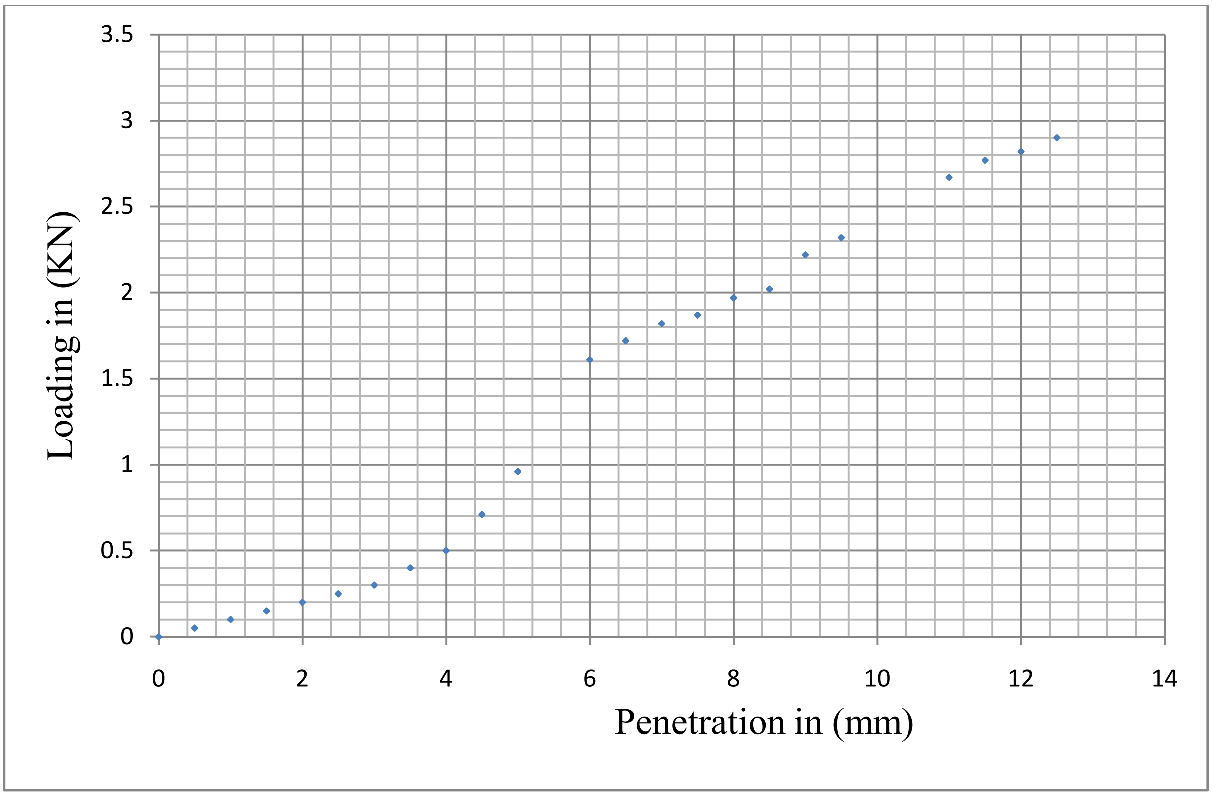
CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (0.616)/ (13.440)*100

= 4.58%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (1.16)/ (20.160)*100

= 5.75%

9) Figure – 3.4.2, Soaked (96 hrs)



CBR corresponding 2.5 mm penetration = (test load)/ (standard load)*100, = (0.414)/ (13.440)*100

= 3.08%

CBR corresponding 5 mm penetration = (test load)/ (standard load)*100, = (1.19)/ (20.160)*100

= 5.90%

3.5.1 Variation of CBR with time of soaking

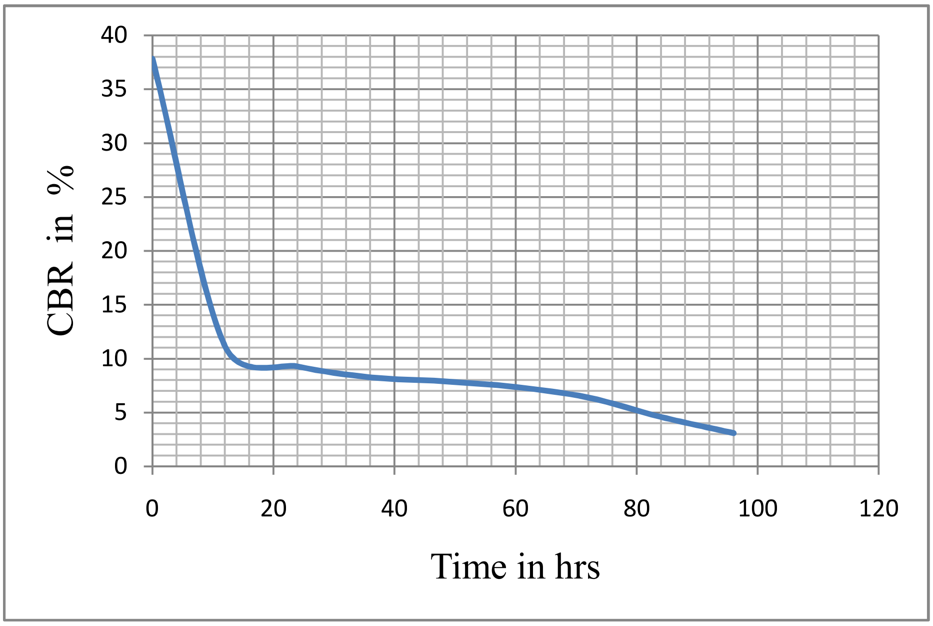


Figure – 3.5.1

3.5.2 Variation of CBR with moisture content

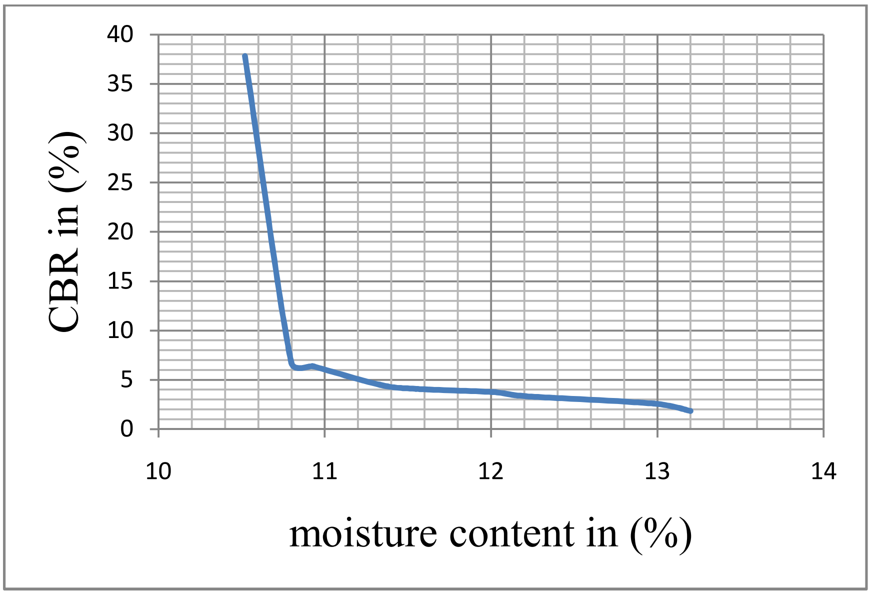


Figure – 3.5

3.6 Variation of moisture content within the sample

Table – 3.6.1

Time of Soaking	Moisture Content in (%)			
	Sample	**Top**	**Middle**	**bottom**
0 hrs soaking	1	10.87	11.32	11.91
	2	10.28	10.41	11.75
	3	10.29	11.19	11.76
	4	10.85	10.77	11.66
	5	10.28	10.94	12
	Avg. =	10.51	10.93	11.82

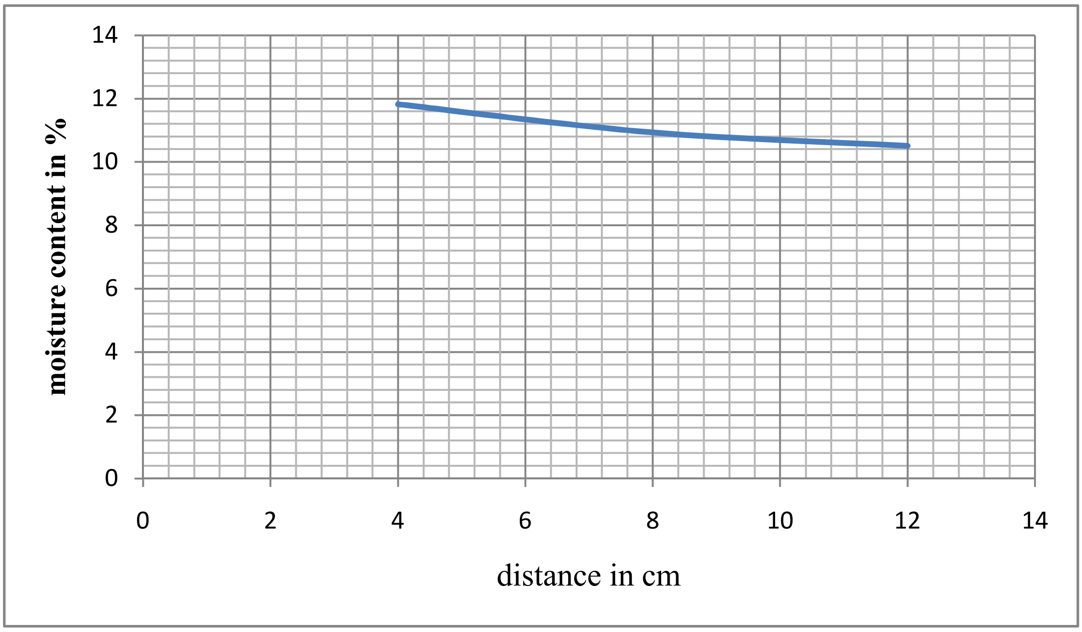


Figure – 3.6.1

Table – 3.6.2

Time of Soaking	Moisture Content in (%)			
	Sample	**Top**	**Middle**	**bottom**
12 hrs soaking	1	11.81	11.62	10.68
	2	11.83	10.91	10.72
	3	10.85	12.33	10.64
	4	12.77	11.59	11.21
	5	11.78	11.65	10.15
	Avg. =	11.81	11.62	10.68

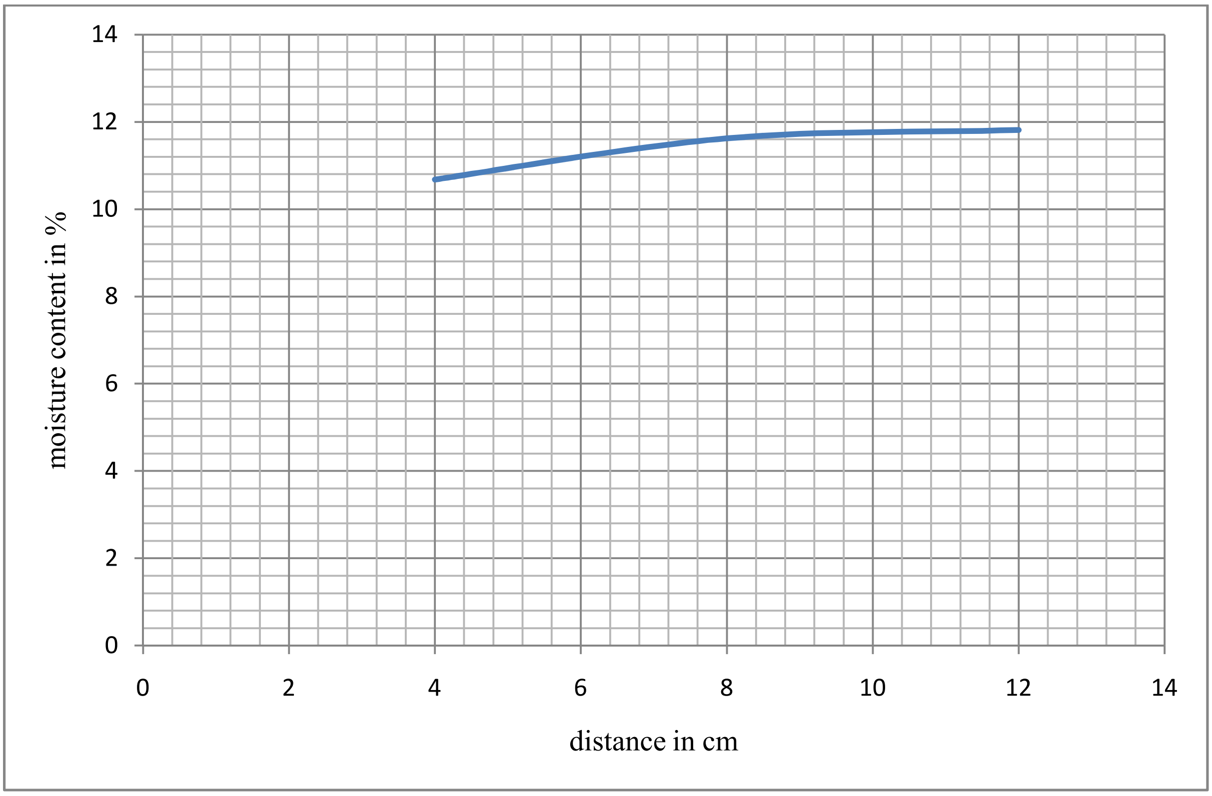


Figure – 3.6.2

Table – 3.6.3

Time of Soaking	Moisture Content in (%)			
	Sample	**Top**	**Middle**	**bottom**
24 hrs soaking	1	13.58	10.06	10.23
	2	11.93	11.73	11.53
	3	12.28	12.15	12.16
	4	13.7	10.75	10.02
	5	8.74	15.37	9.92
	Avg. =	12.04	12.01	10.77

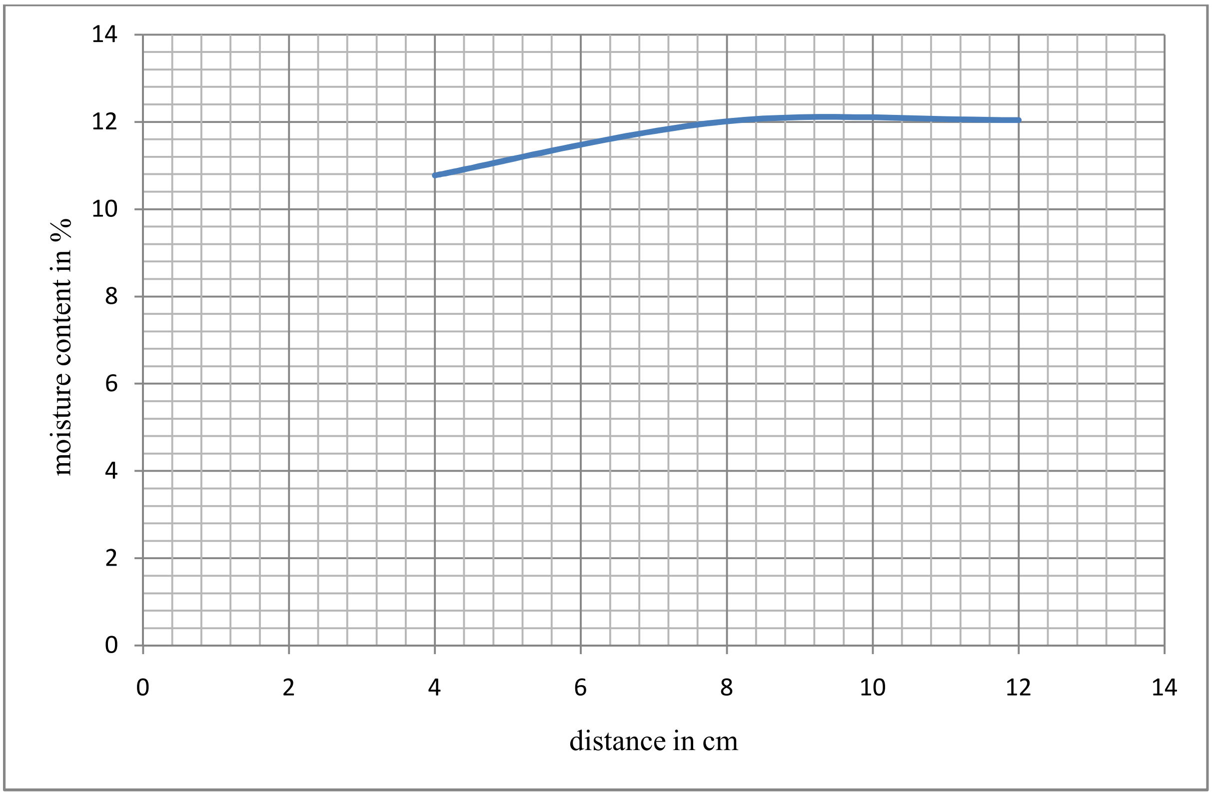


Figure – 3.6.3

Table – 3.6.4

Time of Soaking	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
36 hrs soaking	1	14.64	13.20	11.92
	2	13.70	11.84	11.82
	3	11.96	11.69	11.39
	4	13.88	12.20	11.71
	5	14.22	12.14	11.10
	Avg. =	13.68	12.21	11.58

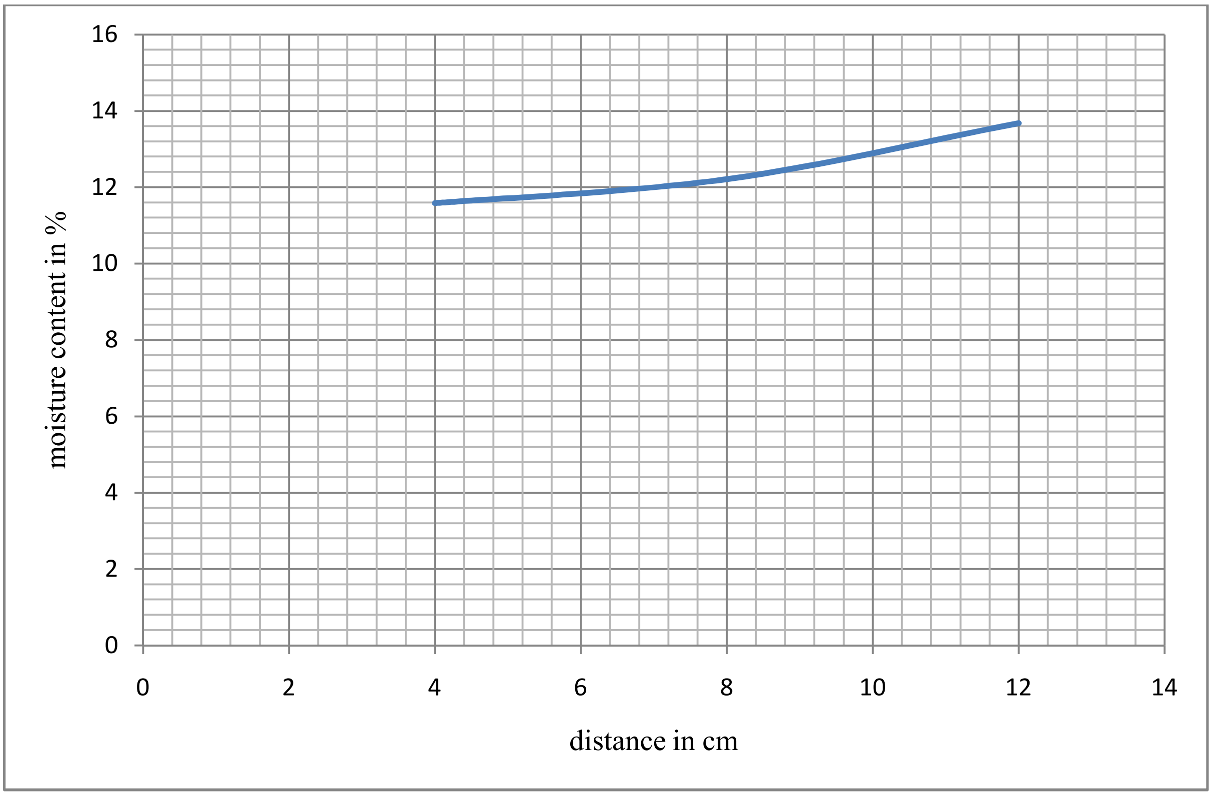


Figure – 3.6.4

Table – 3.6.5

Time of Soaking	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
48 hrs soaking	1	13.38	11.35	11.48
	2	14.12	11.57	10.99
	3	13.30	11.20	11.27
	4	14.77	11.23	11.05
	5	13.19	11.32	10.97
	Avg. =	13.75	11.33	11.15

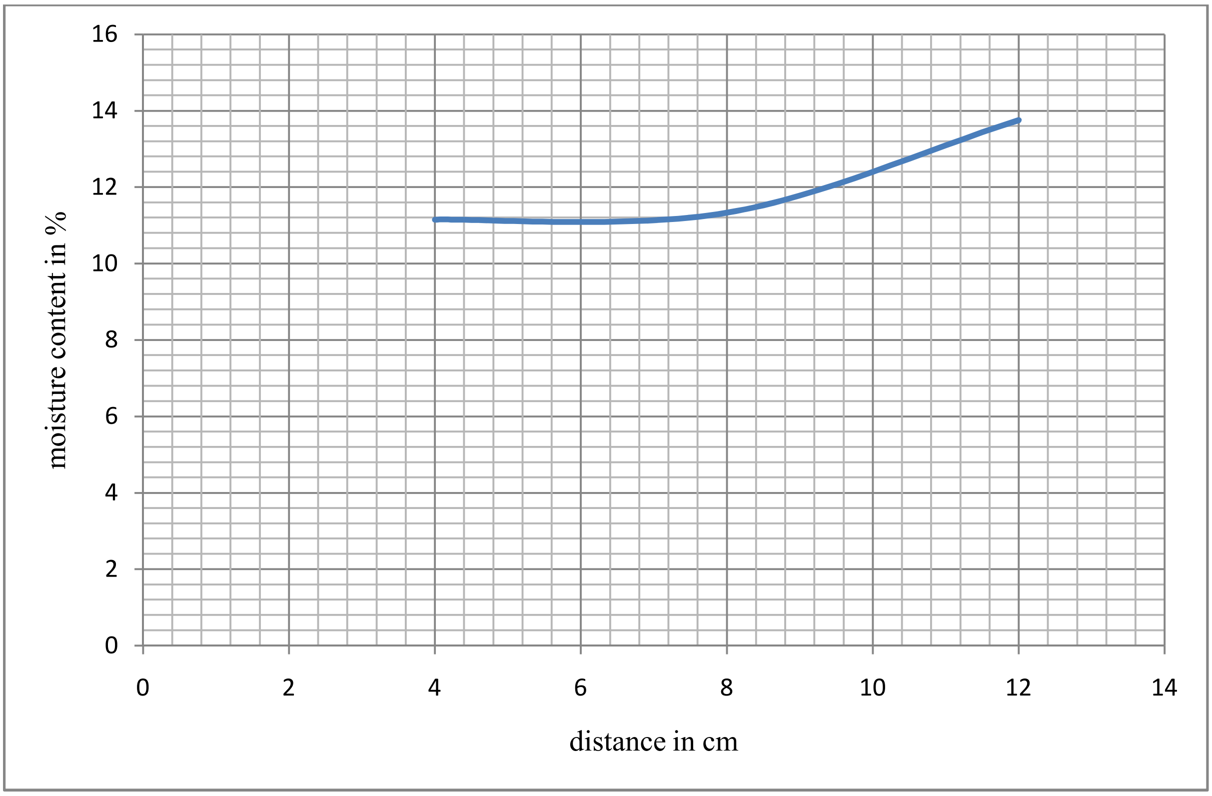


Figure – 3.6.5

Table – 3.6.6

Time of Soaking	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
60 hrs soaking	1	13.83	10.71	10.69
	2	13.52	10.72	10.44
	3	13.92	10.82	10.64
	4	14.16	11.16	10.50
	5	13.64	10.63	10.24
	Avg. =	13.81	10.80	10.50

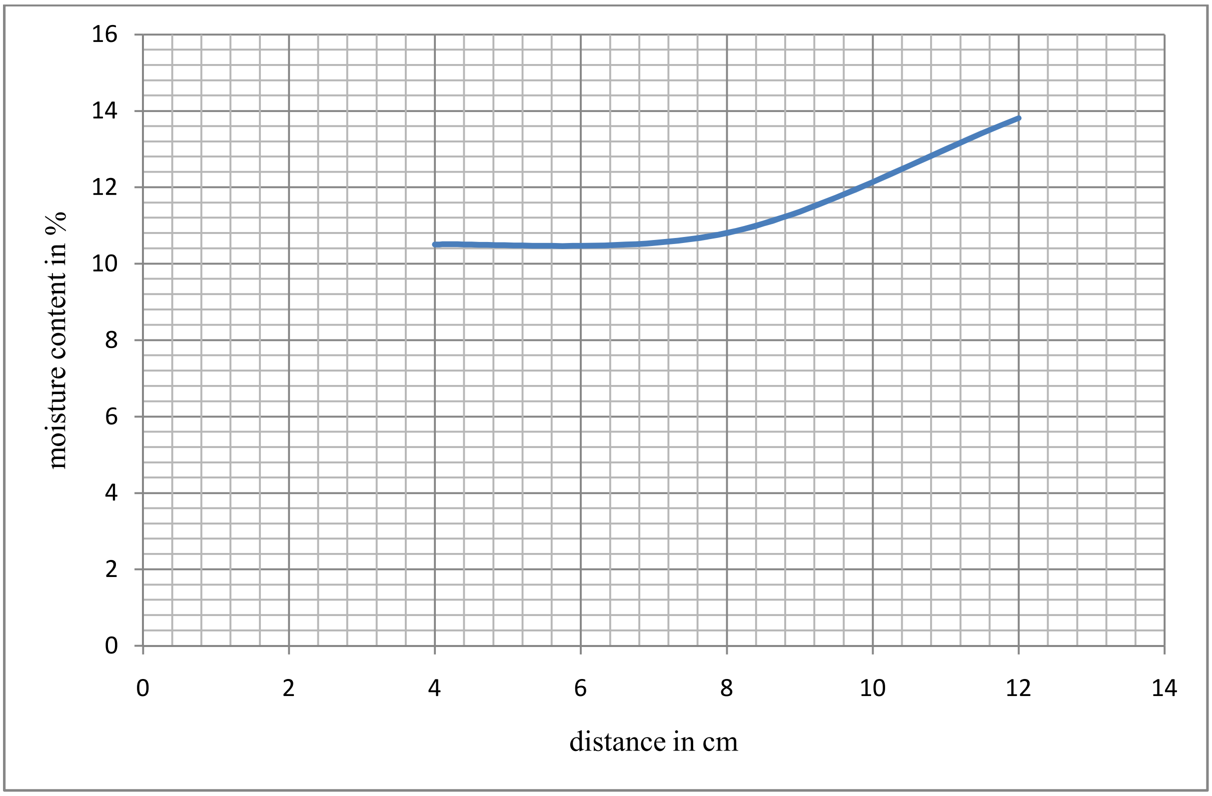


Figure – 3.6.6

Table – 3.6.7

Time of Soaking	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
72 hrs soaking	1	15.17	11.96	11.50
	2	15.42	11.43	11.27
	3	15.06	11.54	11.19
	4	14.52	11.59	11.32
	5	13.62	11.25	10.18
	Avg. =	14.75	11.55	11.09

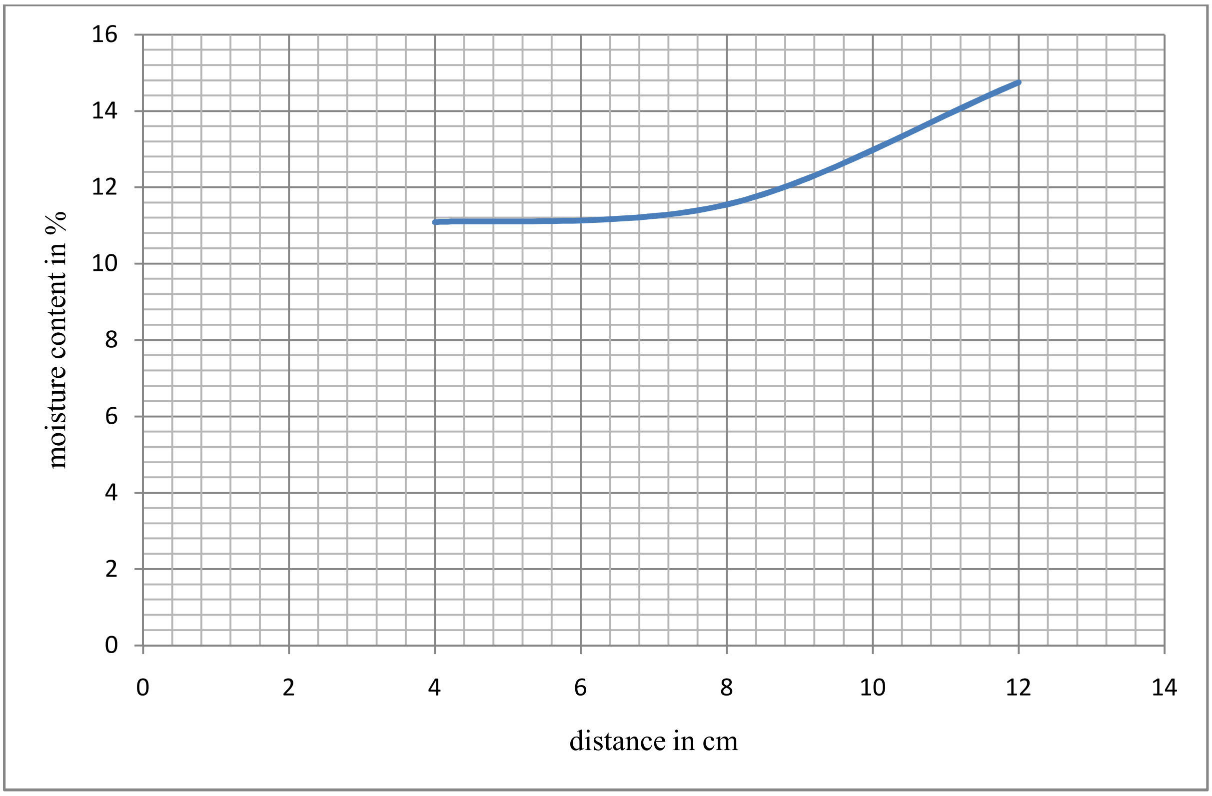


Figure – 3.6.7

Table – 3.6.8

Time of Soaking	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
84 hrs soaking	1	16.15	15.13	12.47
	2	18.46	13.53	14.36
	3	17.36	14.66	12.45
	4	16.51	15.66	12.23
	5	16.62	14.62	13.39
	Avg. =	17.02	14.72	12.98

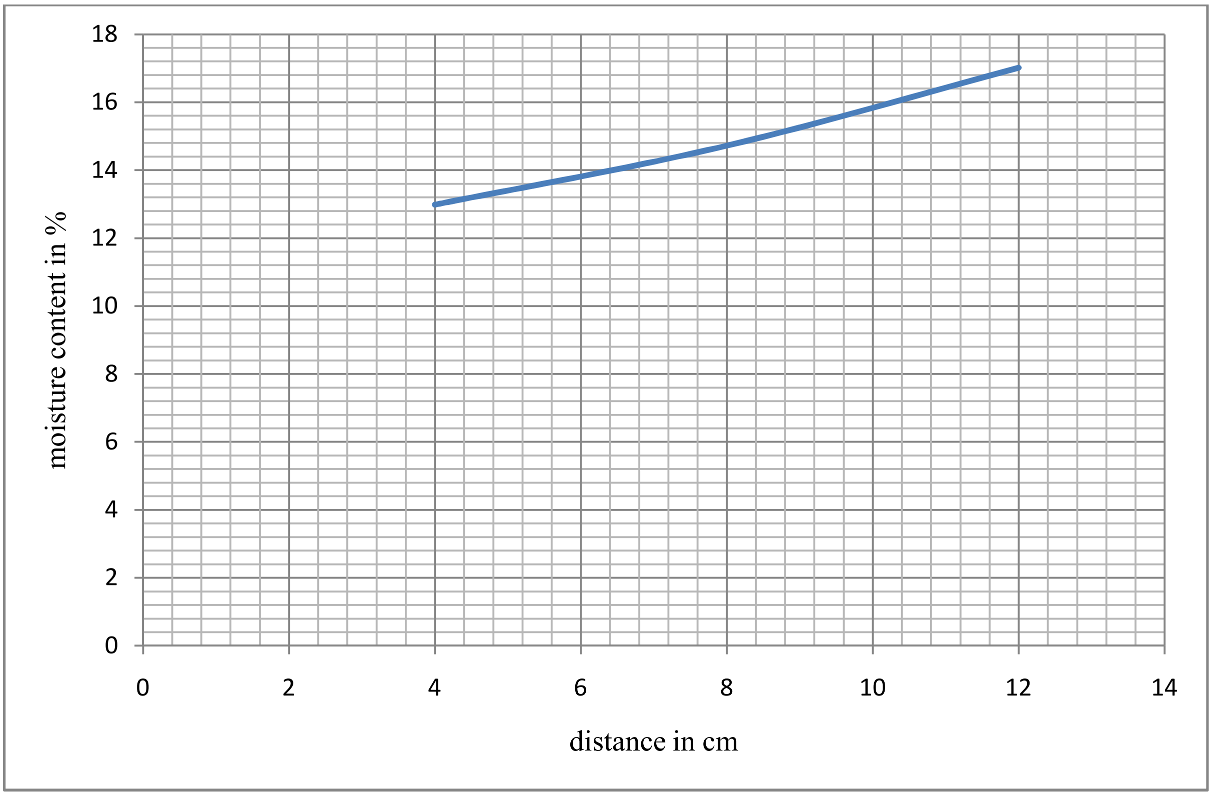


Figure – 3.6.8

Table – 3.6.9

Time of Soaking, Hrs	**Moisture Content in (%)**			
	Sample	**Top**	**Middle**	**bottom**
96 hrs soaking	1	17.21	13.62	12.64
	2	16.52	14.78	13.40
	3	17.90	15.94	12.61
	4	15.86	15.35	13.02
	5	18.56	14.21	13.43
	Avg. =	17.21	14.78	13.02

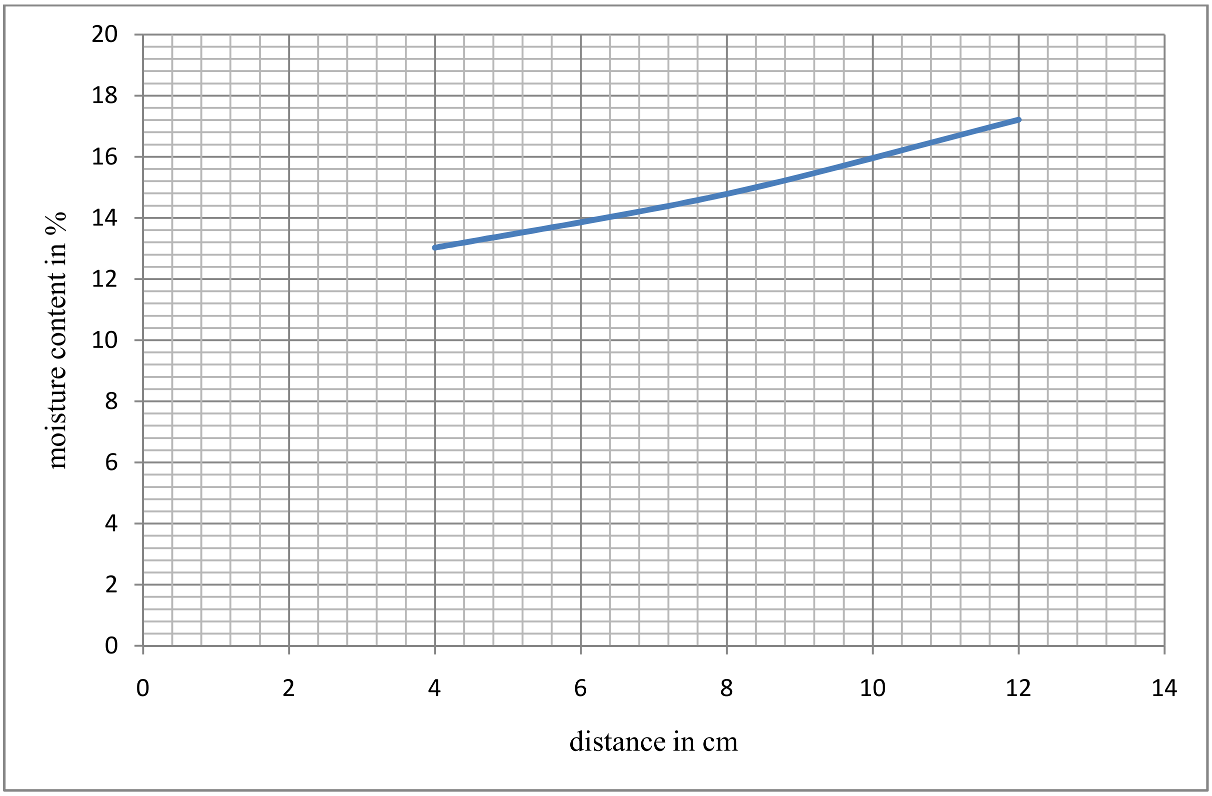


Figure – 3.6.9

CONCLUSIONS

CONCLUSIONS

From the results and discussions described earlier, it is observed that the CBR value of the given soil sample decreases rapidly with time of soaking up to 24 hrs. and then decreases slowly. When soil samples are taken from different points of the CBR sample and tested for its moisture content, it is also observed that the variations of moisture content in a given layer are not significant. However, it is observed that for a longer soaking time, higher moisture content is observed at top layer compared to that in the bottom layer.

3.7 - References

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